PUTTING RESEARCH TO WORK

BRIEF

Fine Aggregate Angularity and Hot-Mix Asphalt Performance

In 2000, the Wisconsin Department of Transportation adopted Superpave design standards for asphalt mixes. These standards limit fine aggregate angularity according to traffic volume and depth, and select binders based on climate and traffic assumptions.

WisDOT practices already matched the Superpave requirements limiting FAA and adjusting binder grades in order to minimize the potential for rutting. Existing practices also increased performance grades by one level for high traffic volume.

What's the Problem?

Before 2000, WisDOT practices limited the amount of natural sand—a fine aggregate—in asphalt mixes to 20%. The angularity of natural sand varies by source; in Wisconsin, many sources yield sand with FAA values well above the acceptable minimum of 40. However, WisDOT specifications require sand in mixtures used for high-traffic roads to score a higher FAA value of 43 to 45.

While implementation of the FAA limits improved upon the arbitrary criteria of limited use of natural sand, these limits do not consider possible interaction with other important factors—like asphalt content and performance grade—that may influence mixture performance and alter acceptable FAA limits.

A clearer understanding of the effects of FAA limits on constructability and mixture resistance to traffic loading could significantly change the acceptable limits, which could affect mixture cost and performance. Also, an understanding of the relative importance of FAA values and their interaction with performance grade and asphalt content could lead to specification changes for Wisconsin. Superpave recommendations encourage adjusting specifications based on local conditions and experience.

Research Objectives

Researchers investigated FAA and its potential interactions with asphalt content and performance grade as it pertains to constructability and rut resistance. Their central hypothesis was that aggregate characteristics like shape, surface texture and absorption properties may interact with mixture components, causing some hot-mix asphalt blends to be more sensitive than others to FAA values. This project aimed to quantify the effect on mixture properties related to pavement performance of interrelated variables including gradation, performance grade, asphalt content, FAA and aggregate source.

Methodology

Researchers tested mixes made with materials from four sources of aggregate commonly used in Wisconsin, choosing a fine blend and an S-shaped blend from each source.

Mix samples were tested in laboratories with the Superpave Gyratory Compactor, which provided densification data. Researchers used a gyratory load plate assembly inside the SGC to determine resultant force data. They then calculated estimates of volumetric properties and frictional resistance at different compaction phases—during the initial stages of construction and in simulated traffic loading phases.

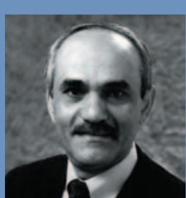
Results

Researchers found that higher fine aggregate angularity values do not necessarily lead to better-performing pavement. Rather, the effects of FAA on pavement performance are highly dependent on coarse aggregate source. Detailed findings included:

• There are significant interactions between FAA and gradation, asphalt content and performance-graded asphalt that affect a mixture's volumetric properties and shear resistance.

• Varying asphalt content is important to critical HMA mixture properties, including volumetric prop-

Investigator



"You cannot judge sand just on FAA values. The values should not be too independent of the source or gradation of the aggregate."

–Hussain Bahia
University of Wisconsin-Madison
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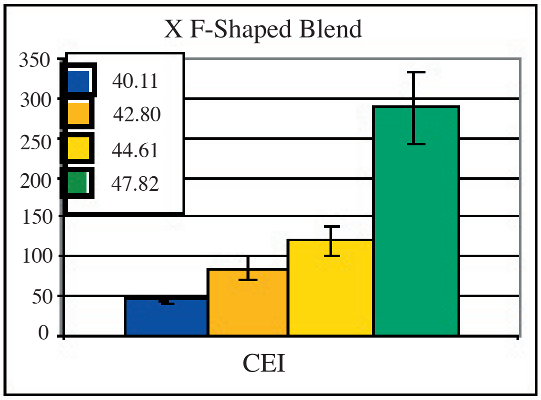
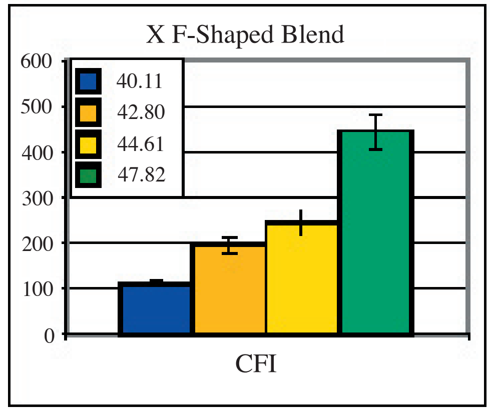
Not pictured:
Anthony Stakston,
University of Wisconsin-Madison





Fine aggregate angularity levels must be precisely managed. The finer the aggregate, the higher its compaction energy index (CEI, a new parameter used in this study) and compaction force index (CFI), and the greater its frictional resistance during compaction (Fig. 4.1, page 35 of final report).

erties and frictional resistance. For the majority of blends examined, its effect was more significant during the initial stages of compaction than the final stages. The effect of asphalt content variation is also highly dependent on aggregate source.

• Varying the performance grade of the binder is also important to critical HMA mixture properties, including volumetric and densification properties. For the majority of mixes examined, its impact was greater during the final stages of traffic loading than the earlier stages of compaction. The effect of performance grade variation is also highly dependent on aggregate source.

• Gradation change exercised less impact than other factors on the response variables in this study. S-shaped blends did not perform significantly differently than fine blends. However, gradation can still affect performance significantly based on angularity and source.

Implementation and Benefits

Since selecting FAA values based on traffic levels alone is not likely to produce better mixes, researchers recommend that the process of determining optimal FAA be flexible enough to accommodate the characteristics of the aggregate source. They propose two new parameters for testing potential HMA mixtures: the compaction energy index and the traffic densification index. The new parameters show promise in complementing volumetric properties, and can with limited equipment modification be used effectively in mixture design selection.

Researchers also concluded that:

• The accepted variation of ±0.5% optimal asphalt content for HMA mixes is too great, particularly for typical Wisconsin mixes, and may need to be reduced to ±0.3%. Further research is recommended.

• The effect of increasing binder performance grades is specific to the aggregate source; the same grade change can increase or decrease resistance to compaction or traffic, depending on its source. The traffic densification index of the specific aggregate source should be evaluated to determine the efficacy of increasing binder performance grades.

Further Research

Researchers recommend laboratory testing of more Wisconsin aggregate sources. Results of testing with the Superpave Gyratory Compactor should then be confirmed with mixture performance testing of rutting, cracking and resistance to compaction in the field.

Project Manager

"We're trying to determine if there is any relationship between making a quality mixture and angularity of aggregates used. What is a good number for aggregate angularity for a specific mix?"

–Leonard Makowski
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This brief summarizes Project 0092-45-98, "The Effect of Fine Aggregate Angularity, Asphalt Content and Performance Graded Asphalts on Hot-Mix Asphalt Performance," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research, Development & Technology Transfer Program, 4802 Sheboygan Ave., Madison, WI 53707.

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